# Experimental and Numerical Investigation of Ablation Kinetics

Completed Technology Project (2015 - 2018)

## Project Introduction

The University of Vermont (UVM) and the University of Michigan (UMI) propose a 2-year experimental and numerical research effort aimed at providing critically needed information on the state of pyrolysis gases leaving a porous char material for a carbon/phenolic ablator and reacting with hot boundary layer species. This proposed activity directly addresses 1) finite-rate gas-surface interactions; 2) finite-rate chemistry of pyrolysis and boundary layer gas interaction; and 3) resin decomposition. The experimental approach for these elements is the use of species-selective, laser-spectroscopic measurement techniques to quantify the chemical composition and thermal state of the gases as they leave the char surface and interact with the plasma boundary layer. The justification for addressing these elements is the lack of such experimental data to guide model development. The proposed experiments involve exposing selected carbon/phenolic material samples to high-temperature plasmas with varying composition (argon, nitrogen, oxygen, and air) in the UVM 30 kW Inductively Coupled Plasma (ICP) Torch Facility. During the tests the interaction zone will be probed using tailored, time-resolved Diode-Laser Absorption Spectroscopy (DLAS) and emission spectroscopic instrumentation. These experiments will establish which species leave the material, and how the composition varies with the introduction of different reacting plasma species (Ar, N, O). A parallel experimental effort will be devoted to developing novel sample test configurations that provide a constant char surface location in the plasma stream by allowing sample movement within the holder. The objective of this work is to establish quasi-steady test conditions to enable spatially resolved Laser-Induced Fluorescence (LIF) measurements of key species. Computations performed by UMI will support the development of this capability by simulating the experimental configuration and test conditions using state-of-the-art numerical codes that include pyrolysis and plasma species interaction chemistry. UMI has direct prior experience of simulating the flow in the UVM ICP Torch Facility. These simulations will help define test configurations and conditions as well as provide continuous feedback on experimental findings. The proposed investigation addresses three of the physical processes of Topic 1 with a set of carefully designed experiments that take advantage of existing laser spectroscopic instrumentation to quantify concentrations and gradients of key reacting species: O, N, H, C, CN, CH, OH. Based on prior work some of these measurements determine surface reaction rates, but in all cases the data will provide a valuable resource for validating the chemistry of advanced ablation models. These validation data sets will be comprised of in situ measurements of key species within the non-equilibrium reaction zone, along with carefully measured plasma test conditions and uncertainty estimates for all measured values. This will facilitate the development of better ablation models, which, in turn, enable more reliable and better-understood heat shields, leading to increased payload and/or mission flexibility.


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## Anticipated Benefits

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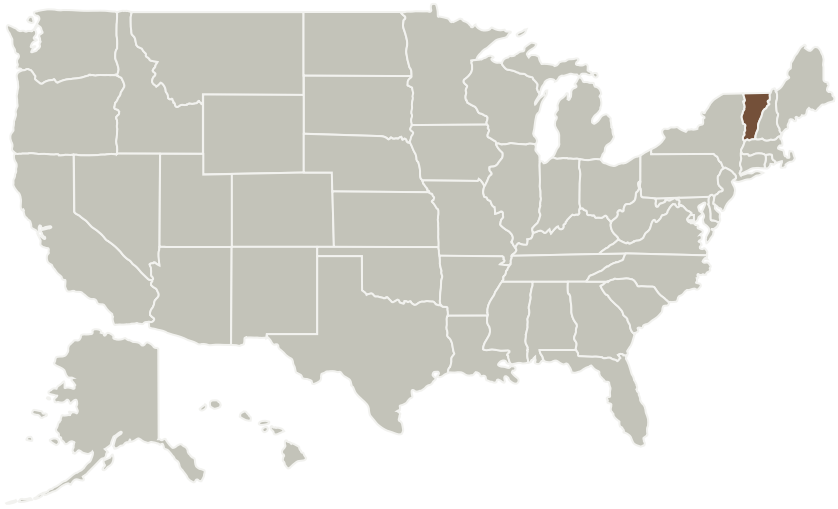
## Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| University of Vermont | Lead Organization | Academia | Burlington, Vermont |

| Primary U.S. Work Locations |
|---|
| Vermont |

## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Organization:**

University of Vermont

**Responsible Program:**

Space Technology Research Grants

## Project Management

**Program Director:**

Claudia M Meyer

**Program Manager:**

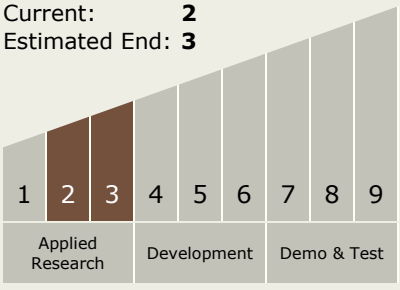
Hung D Nguyen

**Principal Investigator:**

Douglas G Fletcher

## Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



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**Project Website:**

https://www.nasa.gov/directorates/spacetech/home/index.html

## Technology Areas

**Primary:**

- TX09 Entry, Descent, and Landing
  - TX09.4 Vehicle Systems
    - TX09.4.5 Modeling and Simulation for EDL

## Target Destination

Foundational Knowledge